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THREE DECADES OF SPACE ACTIVITIES AT IDR/UPM

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ABSTRACT

Strictly speaking, space related activities at the Escuela Técnica Superior de Ingenieros Aeronáuticos (ETSIA) begun in 1973, when Prof. Ignacio Da Riva got a contract from the European Space Agency (ESA) to compile a handbook on spacecraft thermal control. By the same time, ESA issued an announcement of opportunities offering to the European scientific community the possibility of perform microgravity relevant experiments on board space platform like the European orbital laboratory Spacelab. Prof. Da Riva proposed one of the few selected experiments dealing with fluid physics under microgravity conditions, later flown on Spacelab-1 mission in 1983.
These two events were the starting point where Prof. Da Riva, full professor of Aerodynamics at ETSIA, nucleated a small group of young professors and students located at the Laboratorio de Aerodinámica y Mecánica de Fluidos (LAMF) of ETSIA. Such group was leaded by Prof. Da Riva since its creation till 1991, when Prof. Da Riva died, and it was the seed of the more recently created research institute for aerospace science and technology named "Ignacio Da Riva" (IDR) in his honour. In this communication space related activities performed either at LAMF or IDR during the last three decades are briefly described.

INTRODUCTION

To a great extent the story of Aerospace activities at the Universidad Politécnica de Madrid is linked to the personal story of Prof. Ignacio Da Riva and the group of scientists he directed during almost twenty five years at ETSIA in Madrid. Ignacio Da Riva was born in 1931 in the North of Spain (San Sebastián). He became Aeronautical Engineer in 1956 by the Escuela Especial de Ingenieros Aeronáuticos (after named ETSIA) and he obtained his Ph. Degree in 1959.

Once he was graduated, he started to work at the Instituto Nacional de Técnica Aeronáutica (INTA) in the Aerodynamics Department, where he collaborated with Prof. G. Millán in a wide variety of Fluid Dynamics problems dealing with both Low Speed and Hypersonic Aerodynamics, Magneto-Gas-Dynamics and Combustion [1-5]. During these years Prof. Millán was also the responsible of the Fluid Mechanics and Aerodynamics Department of ETSIA, and he incorporated to teaching activities some of his more outstanding collaborators. Within this frame Dr. Da Riva created the Laboratory of Fluid Mechanics and Aerodynamics of ETSIA, and he directed the design and construction of the first low speed wind tunnel of ETSIA, which was operative from 1962 till 1993 [6]. The aerodynamic performances of such wind tunnel were modest, and it was designed to be used mainly for teaching activities, besides to some experimental work in the field of non-Aeronautical Aerodynamics, like the study of wind-shielding effects of different types of wind-shelters.

In the Spring of 1965 Dr. Da Riva got the position of Full Professor of Aerodynamics at ETSIA. Then he leaved INTA and focused his efforts in teaching as well as in the establishment of a team devoted to advanced research and development tasks at ETSIA. Within this frame he nucleated a small group of young graduates and undergraduate students, settling the basements of the team later known as LAMF-ETSIA (and later on as IDR/UPM), which in a few years reached a well recognized international position within the fields of Spacecraft Thermal Control, Fluid Physics under Microgravity and Space Technology.

Prof. Da Riva also served as an expert in several scientific advisory committees of ESA in the field of fluid physics under microgravity.

SPACECRAFT THERMAL CONTROL

Since 1974 a group of LAMF-ETSIA has been working in the preparation of a Handbook on Spacecraft Thermal Control. The first version of the Handbook was issued in 1975 as a result of a collaboration with Dornier System GmbH (Germany); subsequent work followed at LAMF with the updating in several items and the amendment of new ones [7].

This project has been running since then; at present the handbook has more than 5000 pages bound in five volumes (Spacecraft Thermal Control Design Data Handbook, STCDD ESA PSS 03-108), and it is also available in electronic version. The whole handbook has a modular structure; data are arranged in such a manner that the user could find in one or a few consecutive sheets the information about a particular topic. The handbook is divided in Major Sections which can be classified in three general groups: in the first group, containing Major Sections C, D, E and the first chapter of F (table 1), data about radiation and conduction heat transfer are presented; these data concern only the geometry of the bodies and surfaces considered and no properties of materials are given. The second group (Chapter 2 of Major Section F and Major Sections G, H, and J) includes properties of materials, although some specific properties can be found in the third group (Major Sections K, L, M, N, P, Q, R and S, which is dedicated to thermal control systems.

	Major Section
C	View Factors
D	Holes, Grooves and Cavities
E	Spacecraft Surface Temperature
F	Conductive Heat Transfer
G	Structural Materials
H	Thermal Control Surfaces
J	Insulations
K	Heat Pipes
L	Radiators
M	Phase-Change Capacitors
N	Electrical Heating
P	Louvers
N	Electrical Heating
P	Louvers
Q	Fluid Loops
R	Cryogenic Cooling
S	Existing Satellites
	Cross Reference Index

Table 1. Major Sections of the Spacecraft Thermal Control Design Data Handbook (STCDD ESA PSS 03-108)

FLUID PHYSICS UNDER MICROGRAVITY

Research in low-gravity fluid physics started in Europe in the middle sixties with the aim of solving problems posed by fluid management in spacecraft. Typical problems were sloshing, thermal control, capillary liquid retention, gauging of partially filled tanks, etc. [8].

Studies in capillary-dominated fluid configurations, which are relevant to microgravity, were undertaken in the 19th century by scientists which could not even imagine that in a near future orbital laboratories will be feasible. These scientists put the basis for the later development of this field of fluid mechanics. Microgravity activities at LAMF-ETSIA begins in 1974, when ESRO (the forerunner of ESA) issued and invitation to submit ideas for the definition of the experimental objectives for the First Spacelab Mission.

From the nearly eighty ideas received, thirteen dealt with pure fluid physics, although several more were in the fuzzy fringe between fluid physics and material sciences [9]. Most of these ideas concerning fluid physics were accepted, and the related experiments (see table 2) were implemented in the Fluid Physics Module, developed by FIAT C.R. [10, 11].

1-ES-326	Oscillation damping of a liquid in natural levitation
1-ES-327	Kinetics of spreading of liquids on solids
1-ES-328	Free convection in low gravity
1-ES-329	Capillary surfaces in low gravity
1-ES-330	Coupled motion of liquid-solid systems in near zero gravity
1-ES-331	Floating zone stability in low gravity
1-ES-339	Interfacial instability and capillary hysteresis

Table 2 Experiments performed in the Fluid Physics Module during Spacelab-1 mission.

The experiment proposed by Prof. Da Riva was centred on the analysis of the mechanics of liquid bridges. In many practical situations in crystal growth processing, to obtain material of high and controllable purity, it is necessary to fabricate the crucible from material which is not chemically attacked by the molten phase. This is not always possible, as it happens with rare earth metals, and in this situation, when the contact between the crucible and the melt must be avoided, the floating zone technique is an alternative. Within this technique a molten zone is established between two rods: a charge or feed rod of polycrystalline material and a monocrystalline rod. In the floating zone process, due to either the growing process itself or to non-desired perturbations, a large variety of melt shapes can appear. The melt can be hold between solid rods of equal or unequal diameters, it can be rotated, the supporting rods can be aligned or not aligned, etc., so that a precise knowledge of the behaviour of the hydrostatic stability of these melt shapes is of interest in order to prevent either the breaking of the melt zone or the growing of crystal having undesired shapes.

The equilibrium shapes and stability limits of the floating zone melt under the large variety of disturbances that could arise either accidentally or intentionally during the growing process is a matter of great concern. The study of the problem involves a formidable task both because of the material characteristics of the melt, whose properties are strongly temperature dependant, and because of the complexities associated to the disturbances that could be imposed on the zone. Thence, several simplifications must be introduced in the model. The simplest approach consists in disregarding phase changes, considering a liquid zone held between two solid supports, the so-called liquid bridge problem.

In the simplest configuration a liquid bridge consists of an isothermal drop of liquid held by surface tension forces between two parallel, solid disks as shown in figure 1. Disregarding additional electric and magnetic fields effects, the equilibrium interface shape and hydrostatic stability limits of such a fluid configuration are determined by the slenderness, $\Lambda = L/(2R)$, where L is the distance between the supporting disks and $R = (R_1 + R_2)/2$ is the mean radius; the ratio of the radius of the smaller disk, R_1, to the radius of the larger one, R_2, that is $K=R_1/R_2$, or the equivalent parameter $h = (1 - K)/(1 + K) = (R_2 - R_1)/(R_2 + R_1)$; the dimensionless eccentricity, $e=E/R$, $2E$ being the distance between the disks axes; the dimensionless volume, defined as the ratio of the actual volume V_f to the volume of a cylinder of the same length L and diameter $2R$: $V = V_f/(\pi R^2 L)$; the axial Bond number, $B_a = \Delta\rho g_a R^2/\sigma$, where $\Delta\rho$ is the difference between the density of the liquid and the density of the surrounding medium, g_a is the axial component of the acceleration acting on the liquid, and σ is the surface tension; the lateral Bond number, $B_l = \Delta\rho g_l R^2/\sigma$, where g_l stands for the lateral component of the acceleration acting on the liquid, which forms an angle β with respect to the plane defined by the axes of the disks, and the Weber number (assuming that the liquid bridge is rotating as a solid body with angular velocity ω), $W = \Delta\rho\omega^3 R^2/\sigma$.

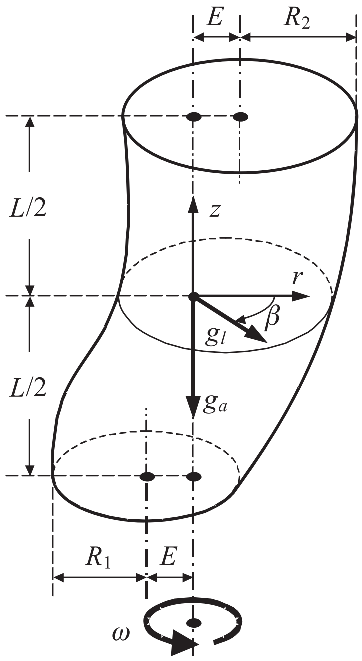

Fig. 1. Geometry and coordinate system for the liquid bridge problem.

The fluid configuration used in Spacelab-1 experiment 1-ES-331 was even simpler than the above described, the only parameters under consideration being the liquid column slenderness, Λ, the eccentricity, e, and the Weber number, W. In the nominal 1-ES-331 configuration the liquid bridge was between equal in diameter circular disks ($h = 0$) and with cylindrical volume ($V = 1$). No relevant information on microgravity levels both in the axial and lateral liquid bridge axes on board orbital laboratories like Spacelab was available at that time, so that in early studies zero-gravity conditions were assumed [12-14]. In the nominal experimental sequence, once formed the cylindrical volume liquid column, several stimuli were applied, involving the axial vibration of one of the supporting disks, rotation of one of the disks, rotation of both disks either in iso-rotation and in counter-rotation, disalignment of the disk-axes with the liquid bridge in solid body rotation, and liquid bridge breakage. Since two runs were foreseen, two different breaking sequences were scheduled. In the first one the breaking should be accomplished by adding liquid and stretching the zone as to maintain the cylindrical shape, and in the second, by just withdrawing liquid at constant disk-separation.

Unfortunately, due to unforeseen perturbations, the development of all the experiments scheduled for the Fluid Physics Module in Spacelab-1 were very far from the nominal conditions [15] . In the case of the experiment 1-ES-331 the liquid bridges formed were very different in shape of cylindrical ones (figure 2) because due to liquid spreading on the lateral surfaces of one of the supporting disks, such disk was substituted in flight by a spare of different diameter. These circumstances strongly reduced the possibilities for a deep analysis of available results, mainly because the lack of appropriate theoretical background to perform such analysis: the first mathematical model for the liquid bridge dynamics was published in the same year than Spacelab-1 flight [16], and theoretical results concerning the stability of liquid bridges between unequal disks appear in the next year [17].

Because of that, practically all the experiments performed in the Fluid Physics Module in Spacelab-1 were repeated again in 1985 during the Spacelab-D1 mission. In the new experiment proposed by Prof. Da Riva and Dr. Martínez (Floating Liquid Zone, FLIZ), nominal experiment procedures were similar to those proposed for Spacelab-1, where due to wetting problems only partial success was allowed [15]. The same Fluid Physics Module, but with corrected end disks (figure 3) and a manual operated syringe for liquid injection, was used. Although several unforeseen liquid bridge breakages took place during the experiment development (*g*-jitter was much higher than measured in previous experiences) the overall result was excellent [18], and a follow-up proposal for Spacelab-D2 was submitted to ESA for further work on liquid bridge rotation and unequal disk stability analysis.

Fig. 2. Picture of a liquid bridge formed in the Fluid Physics Module during Spacelab-1 mission. Observe that the diameters of the supports are not equal.

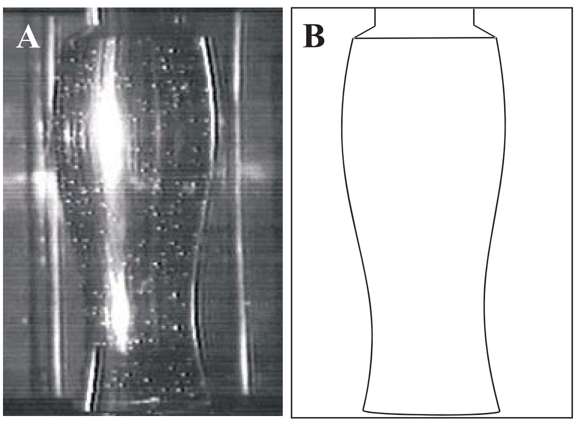

Fig. 3. View and sketch of a liquid bridge formed in the Fluid Physics Module during Spacelab-D1 mission.

Spacelab-D2 flight was scheduled for 1988, but it was delayed until 1993 because of the Challenger disaster. In this Spacelab-D2 mission two experiments supported by LAMF team were performed, one of them dealing with the stability of liquid columns (STACO, figure 4) and a second one concerning the vibration of cylindrical volume liquid bridge (LICORE).

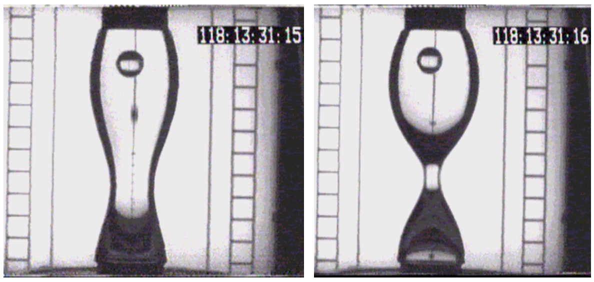

Fig. 4. Pictures just before the breaking of a cylindrical volume liquid bridge by stretching during the Spacelab-D2 mission (experiment STACO).

Real experiments on microgravity fluid-mechanics demand cancelling gravity with inertia forces (taking into account the definition of Bond number that means that the resulting acceleration acting on the liquid column vanishes, $g \to 0$), thus recourse is had to free fall towers, aircraft parabolic flights, sounding rockets and orbiting platforms, depending on the time required. All these recourses have been used at LAMF (now IDR), where together to the above reported experiments in Spacelab-1 Mission, Spacelab-D1 Mission and Spacelab-D2 Mission, some other experiment also dealing with liquid bridges were performed in Spanish satellites UPM-Sat and MINISAT, as well as in TEXUS sounding rockets, and other experimental facilities like parabolic flights and drop towers. The experiments performed both in orbital platforms and in sounding rockets are summarized in table 3.

The existence of all these flight opportunities gave way to a much broader research program, so that together with flight experiments, a large effort was devoted to theoretical studies and to ground simulation of microgravity conditions. Concerning theoretical approaches dealing with liquid bridges, a great effort has been done world wide in the last decades to determine equilibrium shapes and stability limits for a wide range of liquid bridge configurations. As already said, the simplest non-trivial (non-cylindrical) liquid bridge configuration consists of an axisymmetric drop of liquid spanning between two parallel, coaxial, equal in diameter solid disks, in absence of body forces. Early stability studies concerning basic configuration were published more than three decades ago [19-21], although the most relevant result concerning the stability of such configuration were published in the last two decades. Concerning the influence of axial gravity, different attempts have been made to calculate the minimum volume stability limits as well as the maximum volume stability limits both from a theoretical and an experimental point of view. Also the influence of non-equal coaxial disks on the stability limits has been investigated in the last twenty years, as well as the combined effect of both unequal disks and axial gravity. Other axisymmetric (solid body rotation) and non-axisymmetric effects (lateral acceleration, non-coaxial disks) have been also taken into account to analyze liquid bridge stability. A review of the literature dealing with these effects can be found in [22, 23].

Year	OP	SR
1983	Spacelab-1	
1984		TEXUS 10
1985	Spacelab D-1	TEXUS 12
1988		TEXUS 18
1989		TEXUS 23
1992		TEXUS 29
1993	Spacelab D-2	
1994		TEXUS 33
1995	UPM-Sat	
1997	MINISAT	

Table 3. Experiments performed both in orbital platforms (OP) and in sounding rockets (SR) by the LAMF scientific team.

Besides, numerous papers on liquid bridge dynamics have been also published. Leaving apart early studies on the onset of disk rotation [24, 25] and on surface tension driven flows [26], the nonlinear dynamics and breakage of liquid bridges was first studied some twenty years ago, using inviscid, one-dimensional models [16, 27]. An historical review of the most representative publications concerning the breaking of liquid bridges can be found in [28, 29].

Concerning Earth experimentation, most research teams working on liquid bridges under microgravity conditions have developed some kind of Plateau tank for their experimental work. A Plateau tank is just a reservoir filled with liquid inside which another liquid, immiscible with the former and with the same density ($\Delta\rho \to 0$), can be studied as in weightlessness (in some respects). Of course this method does not simulate completely orbital conditions because of the presence of the outer liquid, which affects the dynamics of the fluid column [30], but seems to be very appropriate to hydrostatic analyses, and helps in gaining experience on liquid bridge experimentation. Other method of minimizing gravity effects can be to reduce the size of the experiment to a very small scale ($R \to 0$), say a millimetre or less.

Different Plateau tank and millimetric facilities have been developed at IDR/UPM: The description of these facilities can be found in [31], and some of the main experimental results obtained by using these ground facilities as well as in flight facilities are summarized in table 4.

SPACE TECHNOLOGY

As a consequence of the above described space-related activities, by the end of the eighties some more technology-oriented projects were accomplished at LAMF; some of them were the preliminary study of the fluid science module for Columbus [63], and the development for ESA of a liquid bridge experimentation module which simulated zero gravity using the neutral floatability technique, and was used by the Agency in mission specialists training [64, 65].

Another relevant space project performed by the group headed by Prof. Da Riva was the micro-satellite UPM-Sat, a small scientific, in-orbit demonstration, educational satellite which was designed, built, tested, integrated, and operated by a team of professors, post and undergraduate students, and auxiliary personnel belonging to the Universidad Politécnica de Madrid.

Facility	Configuration	References
SM	$h = 0$, $e = 0$	18, 32-38
	$h \neq 0$, $e = 0$	39, 40
	$h = 0$, $e \neq 0$	13, 15
TX	$h = 0$, $e = 0$	41-44
	$h = 0$, $e \neq 0$	45
DT	$h \neq 0$, $e = 0$	46
PTF	$h = 0$, $e = 0$	27, 30, 47-50
	$h \neq 0$, $e = 0$	51
TOPT	$h = 0$, $e = 0$	52
	$h \neq 0$, $e = 0$	53
TORF	$h = 0$, $e = 0$	54
MLBF	$h = 0$, $e = 0$	29, 55-59
	$h \neq 0$, $e = 0$	23, 60
	$h = 0$, $e \neq 0$	61
	$h \neq 0$, $e \neq 0$	62

Table 4. Some published papers by IDR/UPM team dealing with experimental studies on liquid bridges. SM: Spacelab Missions, TX: TEXUS Flights, DT; Drop Tower, PTF: Plateau Tank Facility, TOPT: Tele-Operated Plateau Tank, TORF: Tele-Operated Rotating Facility, MLBF: Millimetric Liquid Bridge Facility. The second column indicates the disks configuration: equal ($h = 0$) or unequal in diameter disks ($h \neq 0$); coaxial ($e = 0$) or non-coaxial disks ($e \neq 0$).

The UPM-Sat project was initiated by the end of 1990, when the conceptual studies was performed. After the go-ahead of the project by the Rector of the UPM, Prof. Portaencasa (to a great extent responsible of the project funds), the project was almost cancelled because of the decease of Prof. Da Riva in February 1991. However, his colleagues and collaborators decided to continue the project, so that on July 7, 1995, the small Spanish satellite UPM-Sat was launched in French Guiana. UPM-Sat 1, along with the small French satellite Cerise, of similar geometric and weight characteristics. Both micro-satellites travelled into space as secondary payloads on flight V75 of an Ariane IV-40 launcher, whose primary client was the military satellite Helios. Since then, UPM-Sat 1 follows a heliosynchronous polar orbit at an altitude of 670 km, orbiting the Earth every 98 minutes. UPM-Sat, figure 5, was born as an essentially educational project, although the scientific and technological development aspects were also extremely important. Apart from the technological achievement of designing, developing, building, integrating, testing and operating a small satellite at the UPM, the greatest success of the UPM-Sat 1 project has undoubtedly been the experience acquired by the team in charge of the endeavour, which included a mixture of UPM professors, students, and auxiliary personnel.

UPM-Sat was designed to comply with the geometric and weight limitations and the rigidity and stress requirements established for the auxiliary or secondary payloads launched by Arianespace. The main characteristics of this satellite are shown in table 5. Additional technical details on the UPM-Sat 1 platform can be found in [66-69]. The description of the ground segment and in orbit operations are reported in [70], and additional results of the UPM-Sat mission can be found in [71]. The total cost of the project, including the launch and ground segment was approximately two million Euro.

As already pointed out, UPM-Sat is a scientific and in-orbit technological demonstration satellite, but the project was essentially an educational one. The satellite was considered a means rather than an end: the idea was to create a framework in which UPM professors, students, and auxiliary personnel could learn and improve their existing knowledge of the ins and outs of aerospace engineering, in order to create a core of professors specifically oriented towards teaching, research and development in the area of space-related engineering. Due to the educational nature of the project, its first goal was the satellite itself: to find out if the UPM was capable of designing, building, testing, integrating, and operating a satellite with modest technical characteristics, but whose execution would involve all the complexity of a complete space system.

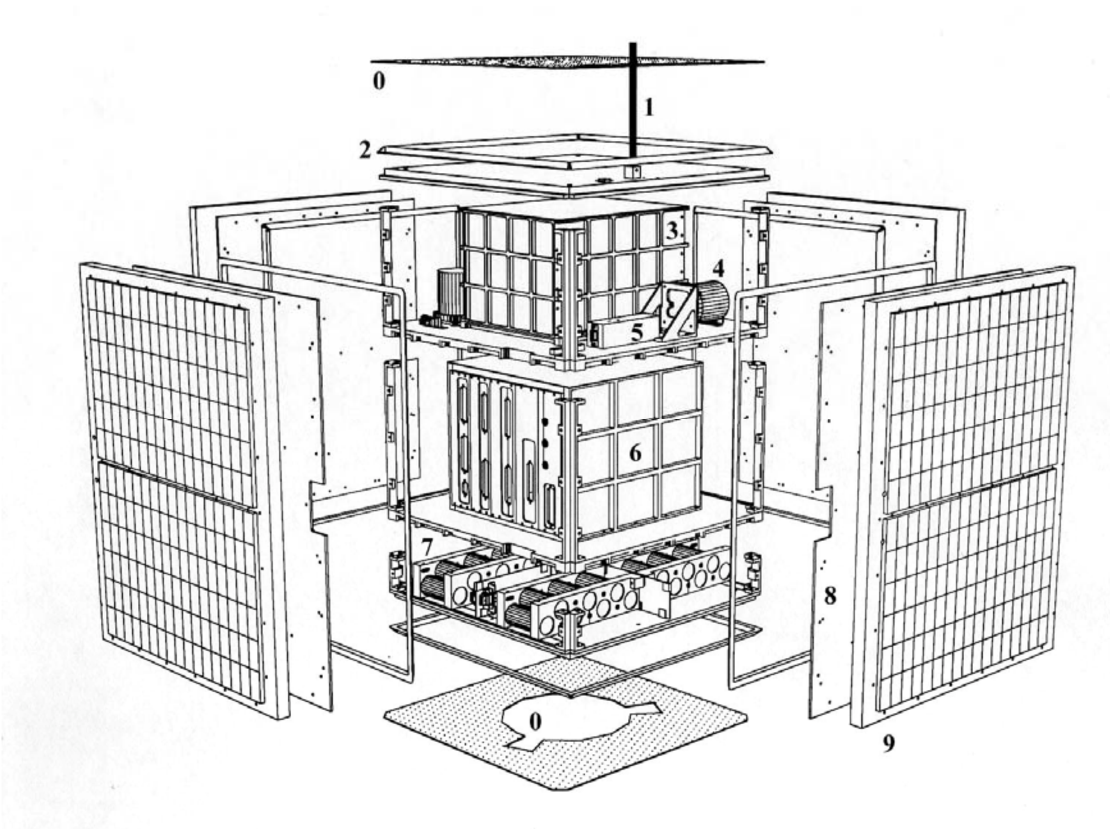

Fig. 5. Exploded view of the UPM-Sat: 0- multilayer insulation, 1- antenna, 2- magnetic coils, 3- liquid bridge cell, 4- gyroscopes, 5- magnetometers, 6- electronics box, 7- batteries, 8- side panels, 9- solar panels.

Mass	47 kg
Dimensions	450 mm × 450 mm × 543 mm (antenna not included)
Orbit	670 km altitude, polar, Sun-synchronous, with a period of 98 min.
Life time	7 months (213 days)
Mission summary	Liquid behaviour under microgravity conditions. Attitude control. Store and forward communications. Solar cells technology
Structure	7075 T73 machined; three layers , shear panels, Aluminium honeycomb solar panel supports
Attitude control	Magnetic stabilisation (magneto-torques plus magnetometers)
Thermal management	Passive (design plus multilayer insulations)
Data management	8 bits 12 MHz 80C31 microprocessor, 256 kbytes RAM, 64 kbytes EEPROM, watch-dog, 64 channels 8 bits DAC, 24 digital outputs and 8 digital inputs. 250 mW power consumption, integral monitoring of voltage and temperature levels, asynchronous communications channel at 9600 bps
Communications	MSK modem at 9600 baud rate, 10 W onboard transmitter in 400 MHz band, omnidirectional antenna.
Energy management	4 solar arrays (3 Si cell solar arrays plus 1 GaAs solar array) 30 W each, 20 W orbit averaged power; 2 batteries NiCd, 20 V bus bar; battery charge/discharge control card, power regulation, switching control card
Launch system	Ariane IV ASAP
Separation system	5SSASAP

Table 5. Main characteristics of the satellite UPM-Sat 1

In addition to this primary goal there were others concerning the use of liquid bridges as space accelerometers [57] and new solar panel technology [72]. The satellite's payload contains an experiment on the behaviour of liquid bridges in zero gravity designed to analyse the possibility of using liquid bridges as accelerometers in space by measuring the deformation of a liquid column while subjecting it to very small accelerations. During the execution of the UPM-Sat 1 project, the development of this payload was delayed for two main reasons. The first concerned the limitations of the platform itself with respect to the power available on board, and its capacity to transmit information to the ground station. The second reason that the liquid bridge payload lost part of its initial importance was a result of the theoretical and experimental progress made by the group in charge of the theoretical support of this experiment: they found that although the use of liquid bridges as accelerometers in space is viable, its development required the creation of a line of technological research comparable in size to the team required to develop the satellite itself. In spite of the problems encountered, it is worth pointing out that due to the studies conducted while adjusting the liquid bridge experiment, new accelerometry techniques in microgravity conditions were developed [73, 74], thereby giving new life to the payload, which has dimensioned to a large extent both the structure and on-board electronics of UPM-Sat 1.

The mission concerning solar panels came about during the purchasing process, when an agreement was reached with the European Space Agency's Centre for Space Research and Technology (ESA/ESTEC, Noordwijk, The Netherlands) in order to use UPM-Sat 1 as a platform for technological demonstration in orbit. As a result, UPM-Sat 1 also contains three experiments with new solar panel technologies. The first involves new aluminium interconnectors for solar panels (in collaboration with DASA, Germany, and ESA/ESTEC, which provided one of the silicon cell panels used on the satellite at zero cost). The second concerns gallium arsenide solar cells (in collaboration with FIAR, Italy, and ESA/ESTEC, which supplied the panel of gallium arsenide cells, also at no cost). The third experiment involves deep emitter n+pp+ silicon solar cells (in collaboration with the UPM's Instituto de Energía Solar, which provided two small solar cells which are mounted on the bottom of the satellite).

After the UPM-Sat project other relevant tasks dealing with space research and development have been undertaken, The payload CPLM (the acronym in Spanish of the experiment Liquid Bridge Behaviour under Microgravity) was designed and manufactured for the Spanish satellite MINISAT [75]. In the field of thermal control IDR/UPM has been involved in the Rosetta mission of the European Space Agency devoted to the exploration of a comet. Within such a frame IDR team has been responsible for the thermal control of the instrument OSIRIS (Optical, Spectroscopic and Infrared Remote Imaging System), in which a fairly large of outstanding European scientific institutions are involved (table 6). OSIRIS is a dual infrared camera system consisting in a high-resolution Narrow-Angle Camera (NAC) for the study of the nucleus of the comet, and a Wide-Angle Camera (WAC) designed for recording dust and gas emissions on the surface of the comet [76].

SCIENTIFIC CONSORTIUM
Max-Planck-Institut für Aeronomie, Germany Laboratoire d'Astronomie Spatiale, France Università di Padova, Italia Instituto de Astrofísica de Andalucía, Spain Uppsalaobservatoriets Nyhetstjänst, Sweden ESA / ESTEC, Netherlands
TECHNOLOGICAL PARTNERS
Technische Univ. Braunschweig, Germany INTA, Spain IDR/UPM, Spain

Table 6. European institutions participating in the design, fabrication and testing of the instrument OSIRIS for the ESA mission Rosetta.

In the same way IDR/UPM has been the responsible of the thermal control of the balloon-borne telescope SUNRISE, which will be flown on a balloon at stratospheric altitudes to analyze the structure and the dynamics of the solar magnetic field. SUNRISE is participated by the institutions listed in table 7, and it can be considered as a precursor of the telescope VIM, one of the payloads of the Solar Orbiter mission of the European Space Agency.

SCIENTIFIC CONSORTIUM
Max-Planck-Institut für Aeronomie, Germany
Kiepenheuer-Institut für Sonnenphysik, Germany
High Altitude Observatory, Colorado, USA.
Lockheed-Martin Solar and Astrophysics Lab., Cal., USA.
Instituto de Astrofísica de Canarias, España
TECHNOLOGICAL PARTNERS
INTA, Spain
IDR/UPM, Spain

Table 7. Institutions participating in the design, fabrication and testing of the balloon-borne telescope SUNRISE.

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